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The Pennsylvania State College
The Graduate School
Department of Agricultural and Biological Chemistry

THE YIELD, COMPOSITION AND QUALITY OF PENNSYLVANIA
CIGAR-LEAF TOBACCO AS INFLUENCED BY CERTAIN
ENVIRONMENTAL CONDITIONS

A Thesis

by

Arthur LaRue Haskins

Submitted in partial fulfillment
of the requirements for the degree of

Master of Science

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February 14, 1944

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THE YIELD, COMPOSITION AND QUALITY OF PENNSYLVANIA
CIGAR-LEAF TOBACCO AS INFLUENCED BY CERTAIN
ENVIRONMENTAL CONDITIONS

Introduction

For more than 50 years problems relating to the tobacco industry of Pennsylvania have constituted a program of research by The Pennsylvania State College. This program has been aided materially in recent years through the coöperation of the Bureau of Plant Industry of the United States Department of Agriculture.

From 1893 to 1912 field experiments were instituted and conducted in various parts of Lancaster County; the center of this particular industry. However, from 1912 to 1931 field investigations were largely confined to an experimental field located on the Hibshman farm near Ephrata, Pennsylvania.

In 1931 detailed plans for further field investigations were made and for this purpose an experimental field was selected on the Lefever farm near Roseville, Pennsylvania; just north of the city of Lancaster, Pennsylvania.

These latter field experiments featured a three-year rotation of wheat, legumes and tobacco in order. When tobacco was produced on the individual plots of a given tier it received varying quantities and kinds of

commercial fertilizers, with or without experimental treatments of farm manure.

The first crop of tobacco was produced on these particular plots in 1932. As the years progressed, however, it became evident that for the best results, legumes should not immediately precede tobacco in the rotation. Therefore, in 1938, these field experiments were supplemented by others where corn immediately preceded the tobacco crop. The original field comprised 10 acres, a detailed account of which has been made by Thomas and Haley (24). The additional acreage adjoined this field.

In 1940 the results obtained over the nine-years period on plots where tobacco followed corn or legumes in the rotation, were submitted by Haley, Street, Farrell and Reid (8), and the field experiments on the Lefever farm were discontinued.

In 1941 a new experimental field was selected on the Esbenshade farm, a short distance away from the Lefever farm, and the first crop of tobacco was produced on this new site in 1941.

The Experimental Field

The experimental field on the Esbenshade farm totals 22 acres. The soil is a Hagerstown Silt Loam,

which is typical of that region. It was regarded as having a fairly high degree of productivity when acquired for experimental purposes. Some parts of this particular field are somewhat lower than others and water may accumulate at times during the growing season and hence the tobacco grown thereon may not be normal for the season or treatment. To overcome these conditions, in a measure at least, a single treatment is given three plots which are widely distributed throughout the field.

Object of these Investigations

The object of these field experiments was (a) to determine the fertilizer requirements of high quality tobacco when grown in rotations designed to maintain optimum soil conditions; (b) to study the effect of quantity and placement of fertilizers on the production of tobacco; (c) to ascertain the most effective use of farm manure and of cover crops; (d) to determine the effect of irrigation on growth, composition and quality of the leaf and (e) to develop improvements in seedbed management.

These objectives have been set forth in Pennsylvania Agricultural Experiment Station Project 852 and 11 sub-projects. In addition these field

experiments were to include laboratory investigations regarding the chemical composition of the plants grown on the experimental field, as influenced by season, field treatment, curing and fermentation.

Plan of the Experimental Work

The plan of the particular experimental work herein reported involved the selection of tobacco from plots treated in different manners in respect to the use of farm manure and commercial fertilizers. Nine different treatments of three plots each were selected for study. The yields, quality and burn of tobacco from these 27 plots are reported for the seasons of 1941, 1942 and 1943. On the other hand, the analytical work was usually conducted on two plots receiving the same treatment for the seasons of 1942 and 1943.

The field treatment of the plots studied featured the use of farm manure, alone or with varying quantities of phosphoric acid and potash, holding the nitrogen constant at three units when fertilizers were used. In every case tobacco followed corn rather than legumes in the rotation; the individual plots having an area of 1/40th of an acre.

The individual treatments and plot numbers from which samples were taken just before harvesting and after curing are listed in Table I.

Table I
Field Treatments of the Plots Studied

Treatment	Plot Numbers	Field Treatment		
		Manure	Fertilizer	
			Quantity	Formula
		T/A*	lb./A	
A	1, 16, 29	10	-----	-----
B	6, 20, 22	10	1,000	3-9-0
C	3, 19, 27	10	1,000	3-9-6
D	9, 13, 25	10	1,000	3-9-12
E	2, 15, 30	10	1,000	3-9-18
F	8, 11, 24	10	1,000	3-9-24
G	10, 12, 28	10	1,000	3-6-12
H	4, 18, 26	10	1,000	3-12-12
I	64, 79	0	1,000	3-9-12

* 10 tons were applied in 1941, but 15 tons were applied in 1942 and 1943.

Phosphoric acid was applied as triple superphosphate, (48% P_2O_5), and potash as the sulfate (51.9% K_2O). When nitrogen was used two of the three units were carried by nitrate of soda (16% N), and the remaining unit by cottonseed meal (6.6% N).

The Quantity and Distribution of Rainfall

The quantity and distribution of rainfall throughout the growing season have been found to be of overshadowing importance for the production of high quality tobacco. The precipitation should be ample, but not excessive and should be uniformly distributed throughout the growing season. The importance of rainfall distribution has been accented by Haley, Street, Farrell and Reid (8); Haley and Reid (9); Johnson and Valteau (10); and Shear (23).

The rainfall records for the 1941, 1942 and 1943 growing seasons are presented in Table II while the seeding, transplanting, topping and harvesting data are presented in Table III.

Table II

The Amount and Distribution of Rainfall Recorded for the
Seasons of 1941, 1942 and 1943

Day of Month	June Precipitation			July Precipitation			Aug. Precipitation			Sept. Precipitation		
	1941	1942	1943	1941	1942	1943	1941	1942	1943	1941	1942	1943
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1		0.06	0.11	0.08								
2		0.01	0.13	0.24	1.29							
3		trace		2.00	0.03			0.09				
4	0.61	0.01		0.85	0.20		0.01			0.30		0.01
5	0.64	0.10				0.50			0.16			0.02
6	0.21			0.23		0.74				0.27		
7					0.23							0.01
8		0.83	0.02					0.17			0.06	
9		0.01	0.50					2.87			0.13	
10			0.07					0.11	0.18		0.03	
11					0.94	0.54		0.03		0.17		
12		0.11				0.12	0.25					
13	0.35	0.25				1.29		0.34	0.12			
14	0.48	0.08				0.02		1.43	0.66			
15	0.04					0.06						
16	0.33		0.04				0.49					
17		0.33			0.04			0.39				
18	0.82		0.18		0.63	0.01		1.71			0.12	
19					0.09		0.28				0.03	
20							0.47				0.02	
21		0.32			0.12	0.39						
22		0.01				0.34						
23		0.27			trace							

Table II (continued)

The Amount and Distribution of Rainfall Recorded for the
Seasons of 1941, 1942 and 1943

Day of Month	June Precipitation			July Precipitation			Aug. Precipitation			Sept. Precipitation		
	1941	1942	1943	1941	1942	1943	1941	1942	1943	1941	1942	1943
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
24	0.15							0.46			0.05	0.05
25							0.04					
26							1.31					
27		1.33			1.66	0.06	0.49		0.23		0.82	
28		0.10	1.18		0.72	0.01			0.04		2.27	
29		0.02	0.69		0.07			0.07				
30	2.48		0.29	0.11	0.42				0.02			
31				0.10	0.71	0.13						
Total	6.11	3.84	3.21	3.71	7.15	4.21	3.34	7.67	1.41	0.74	3.52	0.19

Table III

The Dates of Seeding, Transplanting, Topping and
Harvesting, Recorded for the Seasons
of 1941, 1942 and 1943

	1941	1942	1943
Seeding	April 14th	May 20th	May
Transplanting	June 12th-17th	June 10th	June 8th
Topping	Aug. 5th-14th	Aug. 11th-14th	Aug. 2nd
Harvesting	Aug. 29th-30th Sept. 8th-13th	Sept. 1st-2nd	Aug. 30th

As may be noted in Table II, the 1941 crop was especially lacking in rainfall at a very important stage in the growth of the plants. No samples of this crop were taken for chemical analysis as the crop showed profound symptoms of nutrient deficiencies. However, samples of both mature and cured tobacco were taken of both the 1942 and 1943 crops.

The season of 1942 was marked by a well distributed but excessive precipitation. Such conditions lead to a marked depletion of the mineral nutrients present in the soil which interfered with normal production. Moreover, those conditions served to restrict normal root development and further restrict the intake of mineral nutrients.

The 1943 season was marked by a dearth of rainfall. The effect on the crop, however, did not appear to be as detrimental as the drought experienced in 1941, which could be accounted for by the stage of growth when the drought occurred.

The Influence of Season, Field Treatment and Curing Process on the Total Yield, Quality and Chemical Composition of Cigar-Leaf Tobacco

The total yields, wrapper production and quality of the tobacco grown on the experimental plots selected for these investigations and for the

seasons of 1941, 1942 and 1943 are presented in Table IV.

Table IV

The Influence of Season and Field Treatment on the Yield and Quality of Cigar-Leaf Tobacco Produced on the Experimental Plots during the Seasons of 1941, 1942 and 1943

Formula of Treatment Plots Fertilizer			Total Yield			Total Wrappers			Quality*		
			1941	1942	1943	1941	1942	1943	1941	1942	1943
			lb./A	lb./A	lb./A	%	%	%			
A	1	0	2.096	1,288	1,566	78	53	69	G	F	F
	16	"	1,965	1,260	1,534	75	46	72	F	F	F
	29	"	1,614	1,408	1,212	69	42	65	F	F	F
	Ave.		1,892	1,319	1,437	74	47	69			
B	6	3-9-0	1,931	1,389	1,542	75	46	75	F	F	F
	20	"	1,908	1,350	1,685	82	35	71	F	F to G	F
	22	"	1,621	1,305	1,502	74	29	69	F	F to G	P
	Ave.		1,820	1,348	1,576	77	37	72			
C	3	3-9-6	1,887	1,357	1,830	75	49	73	G	G	P
	19	"	1,926	1,475	1,581	79	34	69	F	F to G	P
	27	"	1,784	1,487	1,430	74	52	72	P	F to G	P
	Ave.		1,866	1,440	1,614	76	45	71			
D	9	3-9-12	1,817	1,521	1,807	74	59	72	P	F	F
	13	"	1,980	1,470	1,877	78	51	75	F	F to G	F
	25	"	1,830	1,434	1,247	77	40	70	F	F	P
	Ave.		1,876	1,475	1,644	76	50	72			

Table IV (continued)

The Influence of Season and Field Treatment on the Yield and Quality of Cigar-Leaf Tobacco Produced on the Experimental Plots during the Seasons of 1941, 1942 and 1943

Formula of Treatment Plots Fertilizer			Total Yield			Total Wrappers			Quality*		
			1941	1942	1943	1941	1942	1943	1941	1942	1943
			lb./A	lb./A	lb./A	%	%	%			
E	2	3-9-18	2,050	1,508	1,754	79	53	76	G	G	F
	15	"	1,929	1,572	1,420	70	52	74	F	F	F
	30	"	1,909	1,394	1,479	75	34	76	G	F	P
	Ave.		1,963	1,491	1,551	75	46	75			
F	8	3-9-24	1,982	1,429	1,519	75	53	75	F	P	F
	11	"	2,092	1,304	1,615	72	47	77	F	F	F
	24	"	1,810	1,390	1,531	70	47	79	F	G	P
	Ave.		1,961	1,374	1,555	72	49	77			
G	10	3-6-12	1,918	1,505	1,937	79	51	74	F	P	F
	12	"	1,838	1,296	1,837	74	46	74	F	G	F
	28	"	1,828	1,609	1,405	74	53	74	P	F	P
	Ave.		1,861	1,470	1,726	76	50	74			
H	4	3-12-12	1,818	1,476	1,775	73	57	77	G	F to G	F
	18	"	1,884	1,255	1,583	79	14	74	F	F	P
	26	"	1,911	1,364	1,531	79	51	71	F	F to G	P
	Ave.		1,871	1,365	1,630	77	41	74			

Table IV (continued)

The Influence of Season and Field Treatment on the Yield and Quality of Cigar-Leaf Tobacco Produced on the Experimental Plots during the Seasons of 1941, 1942 and 1943

Formula of Treatment Plots Fertilizer			Total Yield			Total Wrappers			Quality*		
			1941	1942	1943	1941	1942	1943	1941	1942	1943
			lb./A	lb./A	lb./A	%	%	%			
I	64	3-9-12	1,338	1,240	1,515	60	52	66	P	G	F
	79	"	1,331	1,174	1,432	58	67	59	F	F	F
	Ave.		1,334	1,207	1,473	59	60	62			

* P = Poor, F = Fair, F to G = Fair to Good, G = Good.

The results on total yield, as indicated by Table IV, show that manure alone, fertilizers alone or manure in addition to six units of potash are not desirable from this standpoint. Formulae of 3-6-12 or 3-9-18 with manure gave better results. This was true, also, in respect to quality. However, in all cases, the seasons had more influence on yield and quality than did the individual field treatments.

The markedly poor yields recorded for 1942 may be attributed to too high a precipitation when growing and to too high a humidity in the curing shed. The curing season was featured by a very high humidity, which favored high enzymatic activity and loss in dry weight and in addition favored a disease known as "shed burn" where further decomposition was effected by means of microorganisms.

The Composition of Cigar-Leaf Tobacco as Influenced
by the Season, Field Treatment and Curing

The leaves selected for the laboratory work were taken from the middle portion of the plants. The samples were dried and the midribs were removed, the remaining portions were then finely ground and kept in air-tight bottles until used.

A number of determinations were made on both organic and inorganic materials in the leaf samples.

Official Methods (15) were used in certain instances, while methods formulated by Pucher, Vickery and Wakeman (16), (17) were used in certain other determinations.

Methods of Analysis

Methods used in the chemical analyses were those best adapted to plant materials, including tobacco.

Moisture: - Moisture was determined on a two-gram sample by drying at 80°C. for three hours in a vacuum drying oven, maintained at a pressure of less than 50 mm. of mercury.

Ash: - Weigh two grams of powdered tobacco in a tared porcelain crucible and place in electric muffle. Allow it to remain there for two hours at 500°C. Cool and weigh.

Alkalinity of the water-soluble ash: - Ash 5 gms. in a platinum dish at 500°C. - cool. Moisten ash with 5% solution of ammonium carbonate, dry and heat to 200°C. to expel excess ammonium salts. Add hot water and disintegrate ash as much as possible with rubber policeman. Filter and wash thoroughly with boiling water into a 600 ml. beaker. Titrate with 0.1 N acid using methyl orange as an indicator.

Report alkalinity in terms of number of m.e. per 100 gms. of sample.

Calcium: - Ignite 10 gms. of the sample in a flat-bottom platinum dish in a muffle furnace. The temperature should be maintained at 500°C. over night. Moisten the ash with 5 ml. of hydrochloric acid and filter into a 250 ml. volumetric flask. Transfer a 50 ml. aliquot to a 250 ml. beaker, add ammonium hydroxide until the iron and aluminum hydroxides start to precipitate and immediately add 10 ml. of acetic acid. Heat to boiling and add 10 ml. of ammonium oxalate and boil until the precipitate is coarsely granular. Cool and allow to stand over night. Filter and wash with water at room temperature until the filtrate is free from oxalates. Break the point of the filter with a platinum wire and wash the precipitate into the beaker in which the calcium was precipitated with hot sulfuric acid (1 + 4) and hot water. Add about 10 ml. of sulfuric acid (1 + 4), heat to about 90°C. and titrate with 0.1 N potassium permanganate. Finally, add the filter paper to the solution and complete the titration.

Potassium: - Potassium was determined on a neutral solution of the ash, using trisodium cobalti-

nitrite as the precipitating agent. A two gram sample of the ground tobacco was ignited in a muffle furnace at 480-500°C. for 24 hours. The resultant ash was transferred to a 400 ml. beaker using distilled water and one ml. of concentrated nitric acid. This solution was heated to boiling and cooled before filtering into a 200 ml. volumetric flask, washed and made up to volume with distilled water.

A 10 ml. aliquot was then measured into a 100 ml. beaker and neutralized by the dropwise addition of normal sodium hydroxide, using a drop of methyl red as an indicator. The solution was then acidified with one ml. of normal nitric acid and the potassium precipitated by the addition of five ml. trisodium cobaltinitrite solution, containing one gram of reagent per five ml. The beaker was placed in a water bath maintained at 20°C. for two hours and then filtered through a tared porous-bottomed porcelain filtering crucible. The transfer was made with 0.01 N nitric acid from a wash bottle. The precipitate was washed ten times with two ml. portions of the dilute nitric acid and five times with two ml. portions of 95% alcohol. Suction was applied until the precipitate was quite dry, the crucible was then wiped with a clean cloth and placed in an electric drying oven for one

hour at 110°C. After cooling in a desiccator, it was weighed. The weight of precipitate multiplied by the factor 0.17216 gave the corresponding weight of potassium.

The composition of this precipitate may be represented by the formula $K_2NaCo(NO_2)_6 \cdot H_2O$.

Total nitrogen: - This was determined by the Kjeldahl method modified to include the nitrogen of nitrates. A one-half gram sample of the ground tobacco was placed in an 800 ml. Kjeldahl digestion flask. To this 40 ml. of concentrated sulfuric acid, containing one gram of salicylic acid were added and the flask rotated to insure a thorough mixing of reagent and sample. The mixture was allowed to stand at least thirty minutes, with frequent shaking. Five grams of sodium thiosulfate were then added and the resultant mixture heated slowly until white fumes appeared. After cooling, ten grams of potassium sulfate, a few crystals of copper sulfate and a Hengar selenium pellet were added and the mixture heated in a moderate flame for one hour after clearing. The flask was allowed to cool and then diluted with 250 ml. of distilled water. A pre-determined volume of Greenbank alkali was added (to make the solution strongly alkaline), followed by a few pieces of mossy zinc,

then connected to the condenser and the contents mixed. The released ammonia was collected in about 50 ml. of saturated boric acid solution, a total volume of about 200 ml. being distilled over. The distillate was then titrated with 1/4 normal sulfuric acid using a mixed indicator of methyl red and methylene blue. A blank determination was run on the reagents employed.

Protein nitrogen: - A one-half gram sample of ground tobacco was placed in a 400 ml. beaker, followed by 100 ml. of 0.5 per cent acetic acid solution. The suspension was then boiled for five minutes and allowed to cool. It was then passed through a filter paper of medium speed and the precipitate washed first with a hot dilute acetic acid solution and then with a small volume of distilled water, the total wash water approximating a total of 100 ml. The filter paper and mass was then transferred to an 800 ml. Kjeldahl digestion flask to which were added fifteen grams of potassium sulfate, a Hengar selenium pellet and 30 ml. of concentrated sulfuric acid. The contents were digested over a moderate flame for one hour after clearing. The flask was allowed to cool and diluted with 250 ml. of distilled water. From this point the procedure is identical with that used for total nitrogen.

Nicotine: - Place a 0.5 gm. sample (corresponding to 5-15 mg. nicotine) in a 50 ml. round bottom flask. Add 2-3 ml. water and an excess of 35% sodium hydroxide, about 4 drops, use phenolphthalein indicator (solid barium hydroxide may be used instead of sodium hydroxide). Begin to heat with the micro-burner and at the same time connect to the steam still. Distil into 3 ml. hydrochloric acid (1 + 4) until the volume of the distillate is 100 ml. Add 1 ml. of 10% silicotungstic acid, $4 \text{ H}_2\text{O} \cdot \text{SiO}_2 \cdot 12 \text{ WO}_3 \cdot 22 \text{ H}_2\text{O}$, for each 10 mg. of nicotine. Stir, place on steam bath for an hour, cool and place in refrigerator over night. Filter on ashless paper, wash with hydrochloric acid (1 + 99), burn off in platinum crucible over low flame, then heat at full heat for 10 minutes. Cool and weigh. Weight of residue $\times 0.1140 \approx$ weight of nicotine.

Volatile acids: - To five grams of powdered tobacco in a 500 cc. Kjeldahl flask add 5 cc. of tartaric acid solution and 100 cc. of carbon dioxide free water. Connect the still; apply heat to the flask, regulating the flame so that boiling takes place in five to eight minutes. At the expiration of ten minutes from the time of applying flames, steam is passed in and 500 cc. of distillate collected at

the rate of 10 cc. per minute. The original volume of solution in the reaction flask is marked with a red crayon and maintained during the distillation. Transfer the distillate to a 600 cc. beaker, heat to 95°C., add six drops of Phenol Red indicator, and titrate with standard 0.02 N sodium hydroxide. Reserve the solution for formic acid determination. Calculate total volatile acids as acetic on a moisture free basis. Blank is considered to be .00073 gram acetic acid. Recovery factor is $\frac{10}{9}$.

Determination of the Non-volatile Organic Acids

Preparation of the organic acid extract: - The organic acids of the tobacco leaf were extracted according to the technique of Pucher, Vickery and Wakeman (16). Two grams of the dried and powdered tissue was acidified to pH 1.0 with 4 N sulfuric acid, mixed with 3.5 grams of asbestos, and extracted with specially prepared ethyl ether in a rubber analysis extraction apparatus for a period of 24 hours. At the end of the extraction period, 25 ml. of (carbon dioxide free) distilled water and 2 ml. of (carbon dioxide free) 5 N sodium hydroxide was added to the ether extract, the system was thoroughly agitated to transfer the acids

to the aqueous phase, and the ether was carefully distilled off. The organic acid extract was made to volume at 100 ml.

Determination of oxalic acid: - Oxalic acid was determined by the method of Pucher, Vickery and Wakeman (16), as follows: A 25 ml. aliquot of the organic acid extract was acidified to congo red with 0.5 N hydrochloric acid. The precipitate that formed was allowed to settle, filtered off on asbestos in a Gooch crucible and washed with water. A drop of methyl red was added to the clear filtrate and ammonium hydroxide was added to a faint alkaline reaction. Two to three ml. of glacial acetic acid were added, followed by 5 ml. of 10 per cent calcium chloride solution. After standing at least two hours, the calcium oxalate was filtered on asbestos in a Gooch crucible and was washed with a little very dilute ammonium hydroxide. Crucible and contents were then transferred to a 100 ml. beaker. Five ml. of 50 per cent sulfuric acid and 20 ml. of water were added; and the solution was heated to boiling and titrated while very hot with 0.02 N potassium permanganate solution.

Determination of citric acid: - Citric and malic acids were determined by the simultaneous method

of Pucher, Vickery and Wakeman (17). In this method, citric and malic acids are oxidized simultaneously, and pentabromoacetone which is formed from the citric acid is separated from the malic acid oxidation product by extraction with petroleum ether, after which the acids are determined separately. The procedure that was used is as follows: A 5 ml. aliquot of the organic acid solution was diluted to 20 ml. with water and 3 ml. of 50 per cent sulfuric acid were added. The mixture was boiled gently for eight to ten minutes to expel traces of ether, cooled, and 1 ml. of saturated bromine water was added. After five minutes the solution was filtered with gentle suction through a Gooch crucible into a suction flask marked at 35 ml., and 2 ml. of 1 N potassium bromide were added. The temperature of the solution was then adjusted at 20 to 22°C. and 5 ml. of potassium permanganate, previously brought to the same temperature, were added. The mixture was allowed to stand in a water bath at 20° to 22°C. for 10 minutes with occasional stirring, and was then chilled to 5° to 10°C. and decolorized with three per cent hydrogen peroxide added dropwise with vigorous stirring.

The oxidation mixture was transferred to a 125 ml. pear-shaped separatory flask, and the suction

flask was rinsed into the separatory flask with 25 ml. of petroleum ether used in small portions. The flask was shaken vigorously and the aqueous layer was drawn off. The petroleum ether was transferred to a second flask. The aqueous solution was shaken again with 20 ml. of petroleum ether and was then put aside for the determination of malic acid. The two petroleum ether extracts were combined and washed four times with 3 ml. of water and the washings were added to the aqueous extract for the malic acid determination. A 3 ml. quantity of four per cent sodium sulfide solution was added to the separatory flask, and the mixture was shaken vigorously. The aqueous layer, which turned reddish, was drawn off into a 50 ml. Erlenmeyer flask. The petroleum ether was then treated a second time with 3 ml. of sodium sulfide and washed three times with 3 ml. of water, the aqueous solutions all being received in the same flask. To this solution was added 2 ml. of 2 N sulfuric acid and a few quartz pebbles; and the solution was boiled gently for three minutes to expel hydrogen sulfide. It was then cooled to room temperature and sufficient 1.5 N potassium permanganate added to produce a red color permanent for 20 seconds. This usually took 0.8 to 1.0 ml. of permanganate. The color was discharged by the addition of a small excess

of specially prepared halogen-free hydrogen peroxide, followed by the addition of 2 ml. of concentrated nitric acid, 3 ml. of standard silver nitrate, 1 ml. of ferric alum indicator solution, and 3 to 4 ml. of ethyl ether. The flask was shaken vigorously to coagulate the silver bromide, and the solution was titrated with ammonium thiocyanate from a micro-burette to a faint salmon-pink color. Inasmuch as the conversion of citric acid to pentabromoacetone is not strictly quantitative, it was necessary to multiply the quality of citric acid determined by a factor of 1.12.

Determination of malic acid: - Malic acid was determined by the method of Pucher, Vickery and Wakeman (17). The aqueous solution, together with the wash fluid from the petroleum ether (obtained as described under the determination of citric acid), was diluted to a 100 ml. A 25 ml. aliquot was transferred to a 300 ml. Kjeldahl flask to which 25 ml. of water, 1 or 2 drops 18 N sulfuric acid and a few quartz pebbles were added. The flask was fitted with a bent distillation tube which extended into a 250 ml. wide-mouth Erlenmeyer flask charged with 10 ml. of a freshly filtered 2,4-dinitrophenylhydrazine solution and 20 ml. of water. The end of the distillation tube was dipped beneath the surface of the reagent in the

receiving flask, and the flame of a microburner was applied to the Kjeldahl flask. The receiving flask was immersed in a cold water bath and the rate of distillation was adjusted so that the receiving solution did not boil vigorously during the distillation. The distillation was continued until the volume of solution remaining in the Kjeldahl flask was reduced to somewhat less than 10 ml., usually taking from 12 to 15 minutes. The receiving flask was then removed and the end of the distillation tube rinsed into it.

The orange precipitate was transferred as completely as possible with water to a small fritted Gooch crucible and dried for a short time at 100° to 110°C. Meanwhile the receiver was thoroughly drained, and the last traces of precipitate were taken up in hot pyridine used in several successive portions but not more than 3 to 4 ml. in all. The pyridine washings were transferred to a 25 ml. volumetric flask. The crucible was then fitted into a rubber stopper, carried on a cylindrical funnel -- which is attached to a test tube equipped with a side arm -- and marked at 20 ml. Boiling pyridine was added in small portions to the crucible; and the contents were gently triturated with a glass rod, after which

suction was applied and the pyridine was drawn through each time. Three or four washings usually were sufficient to dissolve and transfer all the precipitate to the 25 ml. flask used for the rinsing of the receiver. After being cooled to room temperature, the solution was made to volume with pyridine and mixed.

Either a 2 ml. or a 5 ml. aliquot of the pyridine solution was transferred to a 100 ml. flask and 50 ml. of water were added, followed by 5 ml. of 5 N sodium hydroxide. The solution was then diluted to the mark and the intensity of the blue color was determined by the use of an Evelyn Photoelectric Colorimeter, using filter number 580, having transmission limits of 565 to 610 millimicrons. These readings were converted into malic acid equivalents by comparing readings obtained against a standard reference curve which had previously been prepared using solutions of pure malic acid treated in exactly the same manner as described for the aliquot from the organic acid fraction.

A Study of the Ash Content of the 1942 and 1943
Crops of Cigar-Leaf Tobacco

For this study determinations of total ash and alkalinity of the soluble ash were made on mature and cured samples of both the 1942 and 1943 crops. Samples for these and certain other studies were taken from the field at harvesting time and at the end of the curing season from the shed. The results obtained are presented in Table V.

The ash content of the mature leaves of the 1942 tobacco, on a percentage basis, is somewhat higher than that of similar samples of the 1943 tobacco. However, considerably more ash constituents were removed by the latter crop as a greater total yield was obtained that season. This may be noted from the results presented in Table IV.

The reason for determining the total ash of both mature and cured samples was to use this as a basis to determine the loss of dry matter in the shed as a result of the curing process. From the "apparent increase" in the percentage of total ash this value may be computed. However, using the calcium content as a criterion is supposed to be more accurate, owing to the possible contamination of leaves by soil.

The alkalinity of the water-soluble ash is important as a measurement of the form of potassium

Table V

A Study of the Ash Content of the 1942 and 1943 Crops of Cigar-Leaf Tobacco.
The alkalinity being expressed as m.e. per 100 gram sample.

Treatment	Plot Numbers	Total Ash				Alkalinity of the Soluble Ash			
		1942 Mature %	1942 Cured %	1943 Mature %	1943 Cured %	1942 Mature	1942 Cured	1943 Mature	1943 Cured
A	1, 16	-----	21.46	16.82	17.96	--	--	39	28
B	6, 26	-----	20.84	16.70	20.41	--	--	33	24
C	19, 27	20.61	21.88	16.80	17.94	79	77	33	26
D	13, 25	19.10	22.36	17.16	18.45	81	80	28	27
E	15, 30	19.16	21.25	16.81	18.25	71	71	30	25
F	11, 24	20.50	22.69	17.55	18.89	91	77	29	24
G	12, 28	18.60	22.55	16.60	18.64	89	79	35	31
H	18, 26	19.11	21.45	16.91	20.28	88	74	30	24
I	64, 79	17.93	20.07	17.33	17.90	61	64	20	25

within the plant. A high alkalinity indicates potassium in organic form, a low alkalinity is indicative of inorganic combination. It appears, however, that the higher the potassium content, the greater the opportunity for organic combination. Under any condition, however, a high alkalinity is indicative of tobacco of good burning quality. The results obtained substantiate this viewpoint.

The fact that potassium in organic form promotes a good burn was first advanced by Schlösing (22); and later by Van Bemmelen (26); Behrens (1); Garner (2); Nessler (14); Haley (7); Haley, Nasset and Olson (6); and many others.

While the effect of the season overshadows individual treatments, insofar as the alkalinity of soluble ash is concerned, the absence of manure in the field treatment tends toward a low value in this respect.

The alkalinity of the soluble ash appears to be lowered as a result of curing for these two seasons. If no change was effected in this respect the values for the cured would be greater than that of the mature samples. As the results indicate, the values were lower.

A Study of the Calcium and Nicotine Content of
the 1942 and 1943 Crops of Cigar-Leaf
Tobacco and Loss of Organic Matter as
a Result of Curing

The calcium and nicotine content of both mature and cured samples are listed in Table VI. The loss of dry weight during curing is based upon the "apparent increase" in calcium content as a result of this process.

Previous investigations (6) have indicated that more calcium is absorbed by tobacco plants during a dry rather than a wet season, and the results based on the analysis of mature leaves of the 1942 and 1943 crops bears out this contention.

Owing to the fact that calcium appears to be more uniformly distributed throughout the plant than elements such as potassium, or organic compounds such as nicotine, the apparent increase in the percentage of calcium in cured leaves over that of mature leaves is usually employed as a basis for calculating the loss of organic matter as a result of curing. These 18 different plots of 9 different treatments as indicated in Table VI show an average loss of 22.08% and 2.63% for 1942 and 1943 respectively. While this is an arbitrary measurement, it is evident that more loss was incurred in 1942 than in 1943.

Table VI

The Calcium and Nicotine Content of Mature and Cured Samples of the 1942
and 1943 Crops of Tobacco and Loss of Dry Matter on Curing

Treat- ment	Plots	Formula of Fertilizer	Calcium				Nicotine				Loss of Dry Matter on Curing	
			1942		1943		1942		1943		1942	1943
			Mature	Cured	Mature	Cured	Mature	Cured	Mature	Cured		
			%	%	%	%	%	%	%	%		
A	1,16	-----	----	4.24	3.80	3.84	----	2.23	4.82	5.49	-----	1.05
B	6,20	3-9-0	----	4.18	4.00	4.22	----	2.59	5.23	5.66	-----	5.21
C	19,27	3-9-6	3.55	4.21	3.81	4.00	2.00	2.47	4.64	5.52	15.68	4.75
D	13,25	3-9-12	3.43	4.41	3.96	4.01	1.85	2.18	5.11	6.22	22.23	1.25
E	15,30	3-9-18	3.40	4.20	3.61	3.62	1.92	2.49	5.05	5.98	19.02	0.28
F	11,24	3-9-24	3.24	4.33	3.63	3.66	1.69	2.29	5.20	5.82	25.17	0.82
G	12,28	3-6-12	3.17	4.34	3.91	4.00	1.77	2.29	5.01	6.08	26.96	2.25
H	18,26	3-12-12	3.36	4.39	3.89	4.54	1.82	2.55	4.93	5.67	23.47	14.38
I	64,79	3-9-12	3.18	4.08	4.20	4.14	2.04	2.60	5.10	6.29	22.06	0

The curing season of 1942 was marked by high humidity. This favored a greater enzyme activity, but the greatest loss was no doubt due to the action of organisms which degraded the leaves favoring a condition known as "shed-burn".

It is apparent that the season overshadows the production of nicotine over individual treatments. During a moist season a relatively low nicotine content is noted, while under dry conditions the nicotine content is much higher. Based upon the calcium content of mature and cured leaves of the 1942 crop, it appears that no loss of nicotine results during curing. This does not hold for the 1943 season but if the loss of dry matter during curing is computed on the basis of total ash, little if any loss was apparent. These methods of calculation, however, appear to have certain limitations.

A high nicotine content of cigar-leaf is usually indicative of a tobacco that will not ferment well. Some believe that this is on account of the nicotine, others believe that its presence signifies a metabolism leading to the formation of a substrate not adapted for the organisms involved in fermentation.

A Study of the Nitrogen Content of Mature and Cured
Samples of the 1942 and 1943 Crops of
Cigar-Leaf Tobacco

The results obtained on the nitrogen content of mature and cured leaf samples of the 1942 and 1943 crops are presented in Tables VII and VIII.

The results presented in Table VII indicate a relatively high total nitrogen and protein content of the 1942 crop of tobacco. However, it is evident that considerable of the total and protein nitrogen was lost on curing. Such profound effects are abnormal, and may be attributed to the high humidity of the environment, which favored the multiplicity of organisms deleterious to the integrity of the leaf.

In 1943, according to Table VIII, the total nitrogen was somewhat lower and the protein content markedly lower for mature leaves compared to those of the 1942 crop. However, the non-protein nitrogen content of the former leaves was very much higher. Furthermore, considerable of the protein nitrogen was later converted to non-protein nitrogen as a result of curing.

During a drought readily available carbohydrates are utilized in respiration. When these are more or less exhausted, proteins are hydrolyzed and otherwise

Table VII

The Total, Protein and Non-Protein Nitrogen of Cigar-Leaf Tobacco
as Influenced by Field Treatment, Season and Curing

The Nitrogen Content of the 1942 Samples of Cigar-Leaf Tobacco								
Treatment	Plot Numbers	Formula of Fertilizer	Total N Mature %	Protein N Mature %	Non-Protein N Mature %	Total N Cured %	Protein N Cured %	Non-Protein N Cured %
A	1, 16	-----	-----	-----	-----	3.19	1.77	1.43
B	6, 20	3-9-0	-----	-----	-----	3.50	1.97	1.53
C	19, 27	3-9-6	4.58	2.99	1.60	3.50	1.98	1.53
D	13, 25	3-9-12	4.75	3.18	1.58	3.50	1.92	1.69
E	15, 30	3-9-18	4.65	3.17	1.48	3.83	1.90	1.93
F	11, 24	3-9-24	4.63	3.27	1.26	3.84	1.94	1.91
G	12, 28	3-6-12	4.56	3.34	1.22	3.32	1.81	1.52
H	18, 26	3-12-12	4.48	3.07	1.41	3.45	1.75	1.65
I	64, 79	3-9-12	4.03	3.79	1.25	3.22	1.75	1.47

Table VIII

The Total, Protein and Non-Protein Nitrogen of Cigar-Leaf Tobacco
as Influenced by Field Treatment, Season and Curing

			The Nitrogen Content of the 1943 Samples of Cigar-Leaf Tobacco					
Treatment	Plot Numbers	Formula of Fertilizer	Total N Mature	Protein N Mature	Non-Protein N Mature	Total N Cured	Protein N Cured	Non-Protein N Cured
			%	%	%	%	%	%
A	1, 16	-----	4.28	2.00	2.28	4.09	1.45	2.54
B	6, 20	3-9-0	4.65	2.24	2.41	3.87	1.26	2.61
C	19, 27	3-9-6	4.32	1.98	2.34	3.71	1.21	2.50
D	13, 25	3-9-12	4.38	2.12	2.26	4.57	1.54	3.03
E	15, 30	3-9-18	4.40	2.10	2.30	4.05	1.61	2.44
F	11, 24	3-9-24	4.49	2.14	2.35	3.93	1.23	2.70
G	12, 28	3-6-12	4.38	2.16	2.23	4.15	1.41	2.74
H	18, 26	3-12-12	4.12	1.88	2.24	3.47	1.15	2.32
I	64, 79	3-9-12	4.36	2.09	2.27	4.08	1.46	2.62

broken down to form energy-producing materials; oxalic acid being one of the stable by-products of these reactions. Somewhat similar reactions appear to result on curing which is ordinarily a slow drying process, somewhat analogous to that of a drought.

The relatively high non-protein nitrogen found in the plants previous to harvesting indicates that the protein content was somewhat higher during the ripening process. This contention is further strengthened by the high oxalic acid of the mature leaves.

Non-protein nitrogen is found to be an excellent nitrogen carrier for the wildfire organism. During its metabolism on such a substrate considerable quantities of free ammonia are liberated. If such reactions take place within the leaf, a "break down" of the tissues take place. The abrupt breaking of a drought followed by continued wet weather usually favors the penetration of the leaf by these organisms, with disastrous results, especially if the crop is approaching maturity. This condition has been referred to by some investigators as "ammonia toxicity".

A Study of the Potassium Content of the 1942 and 1943
Crops of Tobacco as Related to Burning Quality

For these studies, samples of cured tobacco were taken for analysis and burning tests.

The results of the burning tests for the 1941 crop are likewise listed. It is of interest to note that the growing season of this particular crop closely approached that of 1943.

It is evident from Table IX that a moist season rather than a dry season favors the intake of potassium. The burn of all samples of the 1942 crop was classed as good. The potassium content of these samples averaged 3.87%. On the other hand, the burning quality of the 1943 crop was quite poor. It is interesting to note that the potassium content of these samples averaged but 2.12%.

A Study of the Organic Acid Content of the 1942 and 1943 Crops of Cigar-Leaf Tobacco

In these studies it was decided to determine the volatile acid content of both mature and cured leaves of the 1942 crop of tobacco. It was thought that possibly the volatile acid content would show an increase as a result of curing. However, the results were by no means highly significant in this respect, so that it was decided not to repeat them on the 1943 samples.

Considerable attention was given as to the oxalic, citric and malic acid content of mature and

Table IX

The Potash Content and the Burn of Cigar-Leaf Tobacco as Affected by Field Treatment, Season and Curing

Treatment	Plot Numbers	Field Treatment			Potassium		Burn*		
		Manure	Fertilizer		Cured	Cured	1941	1942	1943
			Formula	Quantity	1942	1943			
		T/A		lb./A	%	%			
A	1, 16	10	-----	-----	3.19	2.32	F to G	G	P
B	6, 20	10	3-9-0	1,000	3.74	2.43	P to F	G	P to F
C	19, 27	10	3-9-6	1,000	4.28	1.97	P	G	P
D	13, 25	10	3-9-12	1,000	4.13	2.26	F	G	P to F
E	15, 30	10	3-9-18	1,000	3.96	1.75	F	G	P to F
F	11, 24	10	3-9-24	1,000	4.62	2.37	P	G	P to F
G	12, 28	10	3-6-12	1,000	4.05	2.27	P to F	G	P to F
H	18, 26	10	3-12-12	1,000	3.53	2.25	P to F	G	P
I	64, 79	0	3-9-12	1,000	3.53	1.43	P	G	P to F

* P = Poor, P to F = Poor to Fair, F = Fair, F to G = Fair to Good, G = Good.

cured tobacco of both crops. The results obtained are presented in Tables X and XI.

The oxalic acid content of both matured and cured samples of the 1942 tobacco was lower than that obtained for 1943. At this point it may be stated that a low oxalic acid content usually is associated with good burning tobacco and one which ferments readily. On the other hand, a high oxalic acid content is evidence of poor quality tobacco, both from the standpoint of burn and ease of fermentation.

It may be noted that the malic acid content is higher than that for citric acid in mature leaves, but such a condition is somewhat reversed as a result of curing. This is in agreement with the findings of Garner, Bacon and Foubert (5), and Vickery and Pucher (27). However, the citric acid content of the 1943 tobacco was somewhat higher and the malic acid somewhat lower than that of 1942.

During the curing of the 1942 tobacco a greater decrease of malic acid was noted than held true for the 1943 tobacco. It is readily apparent, therefore, that the effect of the growing and curing season tends to overshadow the effects of a given field treatment.

The term "curing", according to Garner (3), (4); Garner, Bacon and Foubert (5); Loew (11), and others is somewhat indefinite in meaning, being used to include

Table X

The Volatile Acid, Oxalic, Citric and Malic Acid Content of the 1942 Crop
of Tobacco as Affected by Season, Field Treatment and Curing

Treatment	Plot Numbers	Volatile Acids		Oxalic Acid		Citric Acid		Malic Acid	
		Mature	Cured	Mature	Cured	Mature	Cured	Mature	Cured
		mgm./5 gms.	mgm./5 gms.	%	%	%	%	%	%
A	1, 16	-----	9.42	-----	3.00	-----	6.76	-----	3.41
B	6, 20	-----	10.25	-----	2.97	-----	6.62	-----	1.75
C	19, 27	8.01	10.10	1.88	3.07	2.95	7.25	7.27	3.04
D	13, 25	8.95	7.93	2.25	2.89	2.97	8.22	5.38	3.36
E	15, 30	9.02	8.03	2.23	2.81	2.83	7.57	4.39	2.98
F	11, 24	8.75	10.33	2.20	3.04	2.68	6.96	7.65	2.71
G	12, 28	8.01	10.96	2.02	3.05	1.93	6.98	8.00	2.48
H	18, 26	6.88	10.99	2.09	3.17	2.20	6.22	7.80	2.78
I	64, 79	6.65	9.89	2.31	3.11	2.56	4.72	7.21	3.40

Table XI

The Oxalic, Citric and Malic Acid Content of the 1943 Crop of Cigar-Leaf Tobacco
as Affected by Field Treatment, Season and Curing

Treatment	Plot Numbers	Oxalic Acid		Citric Acid		Malic Acid	
		Mature	Cured	Mature	Cured	Mature	Cured
		%	%	%	%	%	%
A	1, 16	3.26	4.05	3.93	4.16	6.13	3.74
B	6, 20	3.20	3.75	3.88	6.25	7.15	5.22
C	19, 27	2.94	3.91	2.64	4.38	6.96	4.66
D	13, 25	3.76	3.67	2.77	4.80	7.02	4.73
E	15, 30	3.38	3.92	3.10	3.99	6.29	3.94
F	11, 24	3.49	4.19	3.71	4.39	5.87	3.94
G	12, 28	3.01	3.65	3.02	5.08	7.54	4.63
H	18, 26	3.24	3.81	2.52	5.01	6.59	5.31
I	64, 79	3.54	4.25	3.16	4.73	7.19	4.87

the separate operations of barn curing, fermentation and aging, while the tobacco grower restricts the term to the process of drying the ripe leaf in a specially constructed shed and under such conditions as will develop the desired properties or qualities. In these investigations the term "curing" has been considered as it proceeds in the curing shed.

Curing is essentially a life process, as is shown by the fact that killing the protoplasm by excessively low or high temperatures or by means of poisons such as chloroform effectively prevents normal curing.

According to Valteau and Johnson (25), the relative humidity is a very important factor in curing. As the leaves slowly die and become yellow in color a humidity of 85% is desirable. If it exceeds 90% shed-burn may result. On the other hand, if the humidity is much less than 85%, the tobacco may dry out too rapidly and result in an imperfect cure.

The temperature of the curing shed is another important factor to be taken into consideration. Leaf activity practically ceases at 40°F. but becomes more active as the temperature increases. The best temperature for the first stage of curing, or the yellow stage, according to Valteau and Johnson (25), lies

between 60°F. and 100°F.

The chemical changes taking place during the curing process are numerous. As a result of thorough curing all the starch and reducing sugars are said to disappear, and there is a decrease in pentosans and malic acid. On the other hand, there is an increase in citric acid, while the cellulose remains unaffected. At the same time there is said to be a large decrease in nicotine and total nitrogen (5).

The physiological processes characteristic of cigar-leaf tobacco indicate the presence of amylases, proteinases, deamidases, oxidases and other enzymes. The process of starvation to which the leaves are subjected appears to lead to an increased secretion of amylase.

That the chemical changes which take place during curing are enzymatic in nature appear to be well established. Furthermore, these enzymes must of necessity be leaf enzymes, as normally there does not appear to be microorganisms on the leaf surfaces in any great number. As to the role played by leaf enzymes during curing, this has yet to be established. It is apparent, however, that bacterial enzymes play a decided role during fermentation.

The investigations of McKinstry, Haley and Reid (12); Reid, McKinstry and Haley (21); Reid, Haley, McKinstry and Surmatis (18), have established the fact that under the proper conditions of moisture, temperature and aeration, there is a rapid increase in the number of organisms present on or within the tobacco leaves during fermentation. The number and activities of these organisms depend in large measure on the chemical composition of the leaf. Other things being equal, well cured tobacco will ferment more satisfactorily than poorly cured tobacco.

The investigations of McKinstry (13) indicate that malic and citric acids furnish a great deal of the energy requirements for the fermentation organism. Furthermore, a relatively high citric acid content is usually indicative of a tobacco of good quality and one which ferments readily. However, it appears that for best results a considerable part of this acid should be in combination with potassium. Active potassium, liberated during fermentation, suffices to increase the alkalinity of the medium. a condition which further favors the process.

Attention has been called to the fact that ordinarily the curing process is somewhat analogous to the condition of plants undergoing a drought in

the field, as both represent a condition of slow starvation. In this connection it may be stated that the production of oxalic acid in the field and in the curing shed warrants this conclusion.

Summary and Conclusions

This investigation had for its purpose a study of the yield, composition and quality of Pennsylvania cigar-leaf tobacco as influenced by certain environmental conditions including field treatment, growing season and curing. Samples chosen for this study were taken from mature plants in the field from selected experimental plots and additional samples were taken of the same plants at the end of the curing season. Determinations of individual leaf constituents were conducted in both mature and cured samples for the seasons of 1942 and 1943. The results obtained were correlated with the yield and quality of tobacco from the various plots studied and included the seasons of 1941, 1942 and 1943.

Notwithstanding the abnormally dry seasons of 1941 and 1943, and the abnormally wet season of 1942, better yields and wrapper production were obtained when manurial additions were supplemented with fertilizer mixtures of well-balanced nutrients than with manure alone, fertilizer alone or when the manure was supplemented with an unbalanced fertilizer mixture. In this connection it may be stated that fertilizers having the formula of 3-6-12 or 3-9-12 gave better

results than any other individual treatment.

From the standpoint of chemical composition the effect of the growing and curing seasons overshadowed the effects of a given field treatment, and this held for both inorganic and organic constituents.

Studies of ash and ash constituents showed the percentage of total ash to be practically the same for both seasons regardless of treatment. However, more ash was removed by the 1943 tobacco since the total yield was much greater.

The alkalinity of the soluble ash showed a much higher value for 1942 than for 1943. This was due to the fact that there was a greater concentration of organically combined potassium in these particular samples. Such a condition favors the "burn" of tobacco and is usually correlated with the total quantity of potassium absorbed by the plants.

The calcium content and total ash showed an "apparent increase" as a result of curing. This was due to a loss of organic matter during curing, a loss that was far greater in 1942 than in 1943.

Previous investigations showed that under dry conditions the calcium content was greater and the potassium content was considerably lower than under moist conditions. The results submitted show this to

be true for 1942 and 1943.

The nitrogen content of the 1942 and 1943 samples of mature tobacco analyzed practically the same. However, in 1942 the protein content was much higher than the non-protein content. During curing there was a noticeable loss of total nitrogen and a decrease in protein nitrogen as well.

The non-protein nitrogen was quite high in the leaves of the 1943 crop of mature tobacco. Such a condition indicates an hydrolysis of leaf proteins as a result of drought. This condition was aggravated on curing.

The nicotine content was noticeably higher in 1943 than in 1942. It was considered that the "apparent increase" in the nicotine content on curing was due to a loss of organic matter. The nicotine content of all samples of the 1942 tobacco was quite low.

In respect to fixed acids it may be stated that the degradation of proteins as a result of drought is followed by an accumulation of oxalic acid. To a certain extent this holds true on curing as this is a "drying out" process to a considerable degree. It is not surprising, therefore, to find that the oxalic acid content of the 1943 samples was much higher than those of 1942.

The malic acid content of mature tobacco is much

higher than its citric acid content, a condition which tends to become revised as a result of curing. Such conditions were found to hold true for all samples of both the 1942 and 1943 crops of tobacco.

The decrease in malic acid and the increase of citric acid during curing, which was so apparent in the case of the samples of the 1942 crop, is considered desirable. Both of these acids serve as energy material for the organisms of fermentation. It is apparent, however, that for some reason not yet understood that the higher the citric acid content the higher the quality.

The study of the tobacco produced in 1942 and 1943 indicates an overshadowing influence of the growing season. These experiments serve to substantiate the statement that for best results the rainfall should be both ample and well distributed throughout the growing season in addition to ample supplies of organic and inorganic plant nutrients as soil additions.

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